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**Nakagawa**

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(54) **BASE SUBSTRATE, ELECTRONIC DEVICE,  
AND METHOD OF MANUFACTURING BASE  
SUBSTRATE**

2203/085 (2013.01); H05K 2203/107 (2013.01);  
H05K 2203/1147 (2013.01); Y10T 29/49165  
(2015.01)

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H05K 1/113; H05K 2201/09563; H05K  
2203/107; H05K 3/0029; H05K 2201/017;  
H05K 2201/10083; H05K 2203/085; H05K  
2203/1147; H05K 1/0306; H03H 9/0514;  
H03H 9/1021; Y10T 29/49165  
USPC ..... 174/262–266; 29/852  
See application file for complete search history.

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**

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**H05K 3/10** (2006.01)  
**H05K 3/40** (2006.01)  
**H05K 3/42** (2006.01)  
**H03H 9/05** (2006.01)  
**H03H 9/10** (2006.01)  
**H05K 1/03** (2006.01)  
**H05K 3/00** (2006.01)

(52) **U.S. Cl.**

CPC ..... **H05K 1/115** (2013.01); **H03H 9/0514**  
(2013.01); **H03H 9/1021** (2013.01); **H05K**  
**1/113** (2013.01); **H05K 3/4038** (2013.01);  
**H05K 3/426** (2013.01); **H05K 1/0306**  
(2013.01); **H05K 3/0029** (2013.01); **H05K**  
**2201/017** (2013.01); **H05K 2201/09563**  
(2013.01); **H05K 2201/10083** (2013.01); **H05K**

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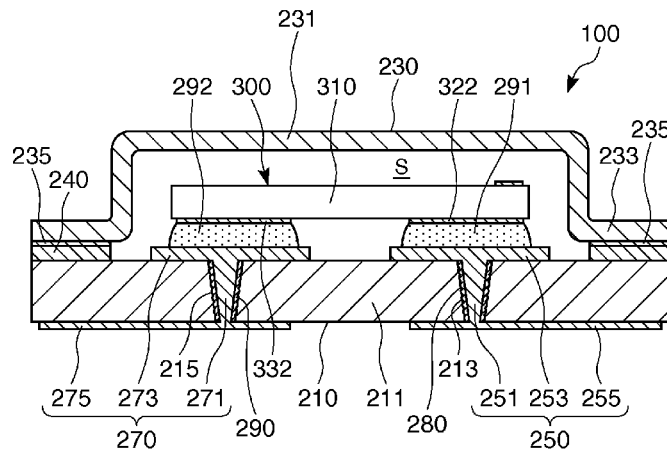
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P.L.C.

(57) **ABSTRACT**

A base substrate includes an insulator board comprising through holes penetrating between two opposed principal surfaces, penetrating electrodes provided within the through holes, and intermediate layers sandwiched between inner surfaces of the through holes and the penetrating electrodes and having surfaces with smaller concavities and convexities than those of the inner surfaces at the penetrating electrode sides.

**9 Claims, 14 Drawing Sheets**



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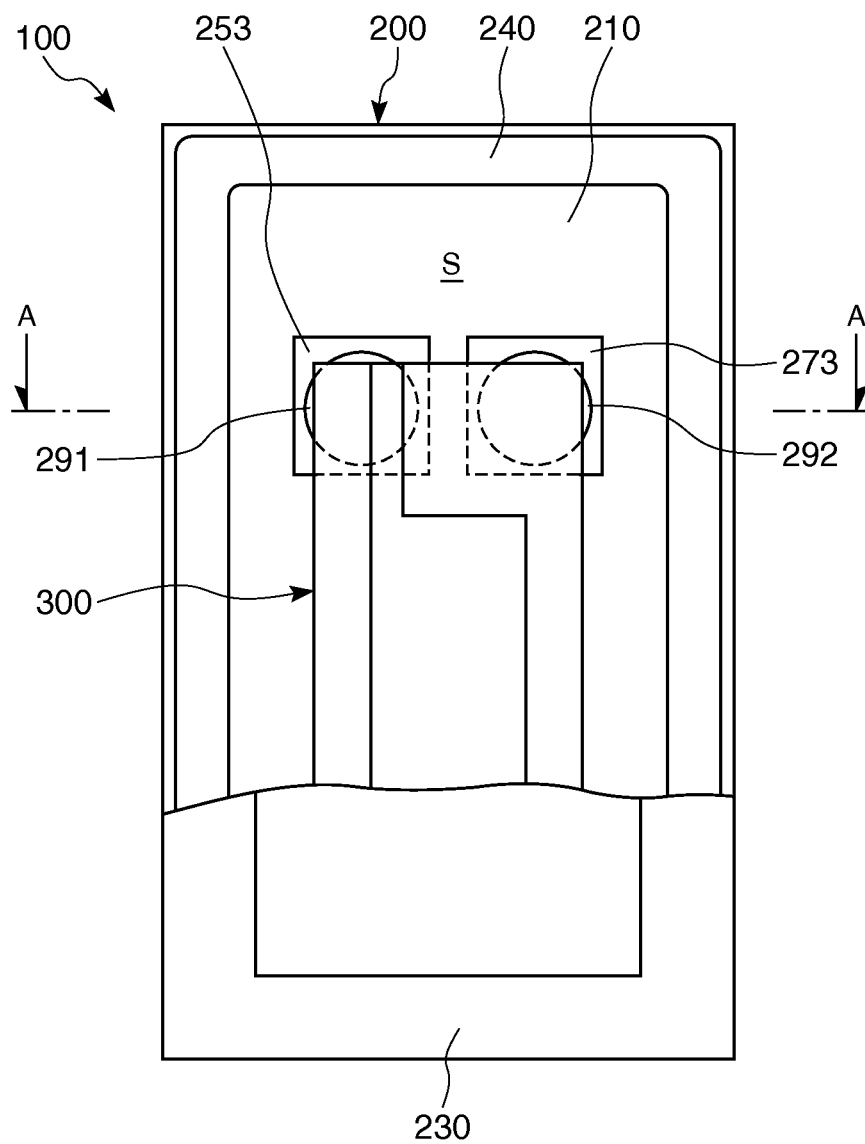


FIG. 1

FIG. 2

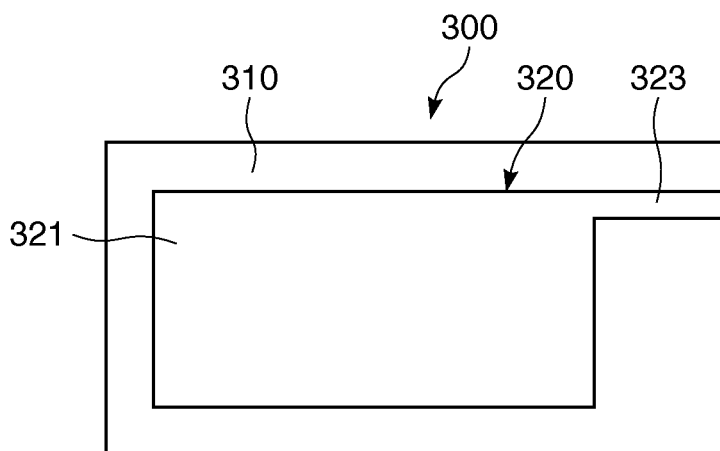


FIG. 3A

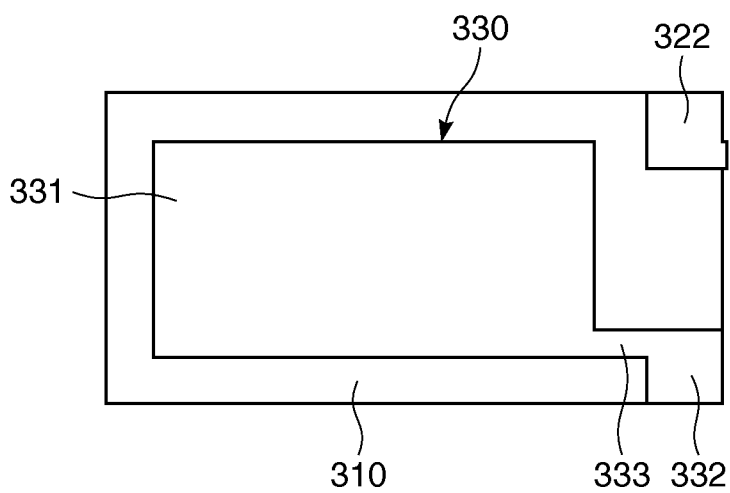


FIG. 3B

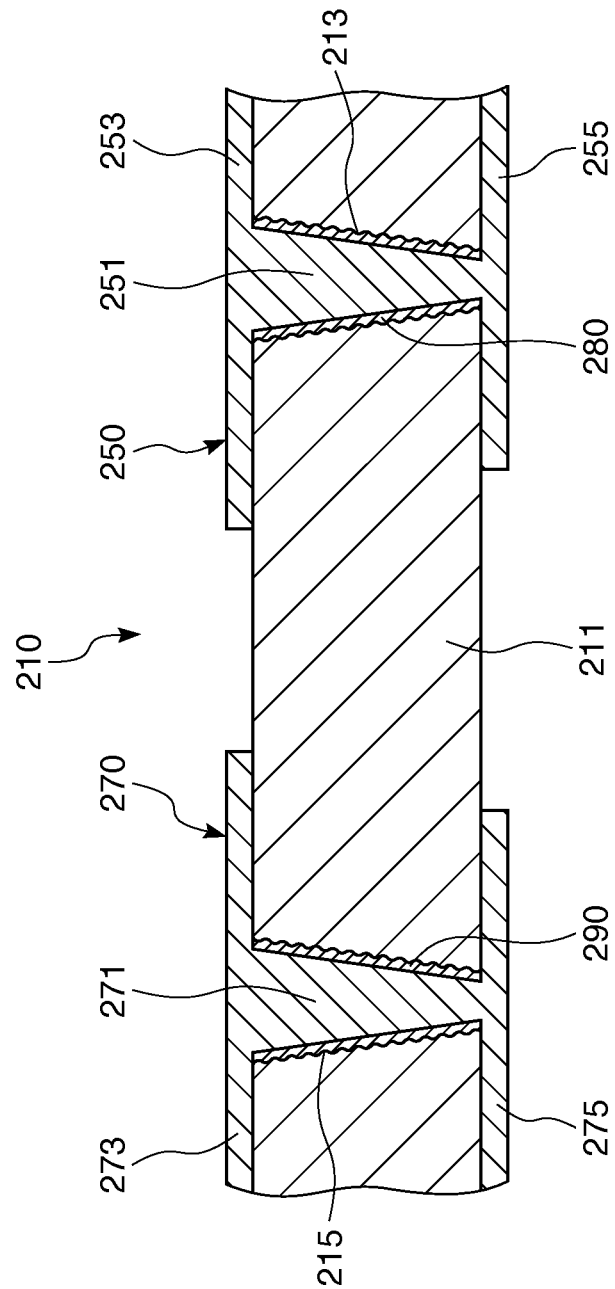


FIG. 4

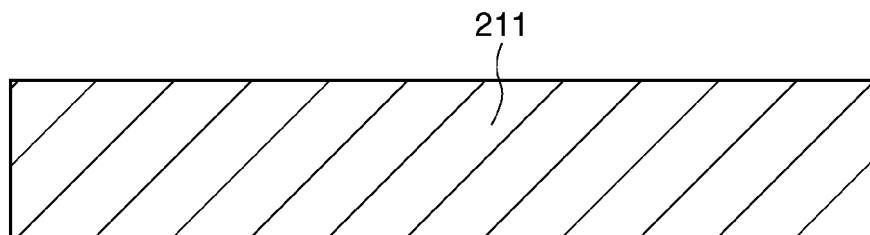


FIG. 5A

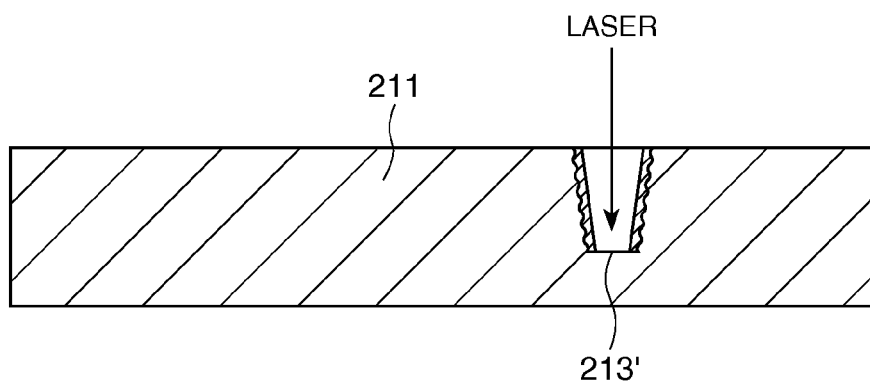


FIG. 5B

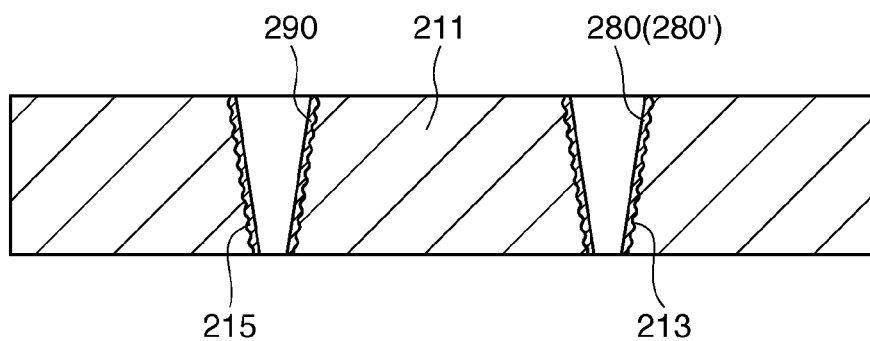


FIG. 5C

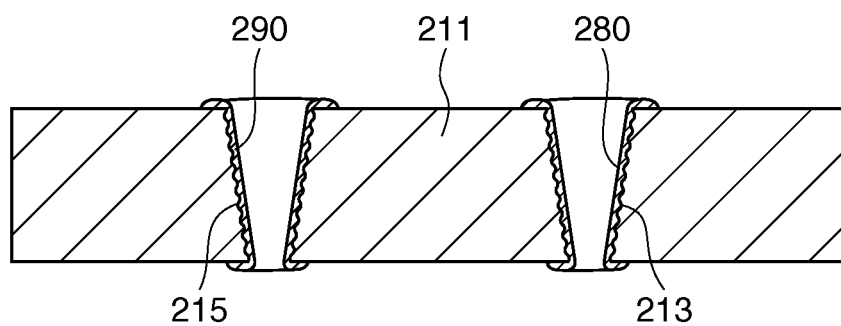


FIG. 6A

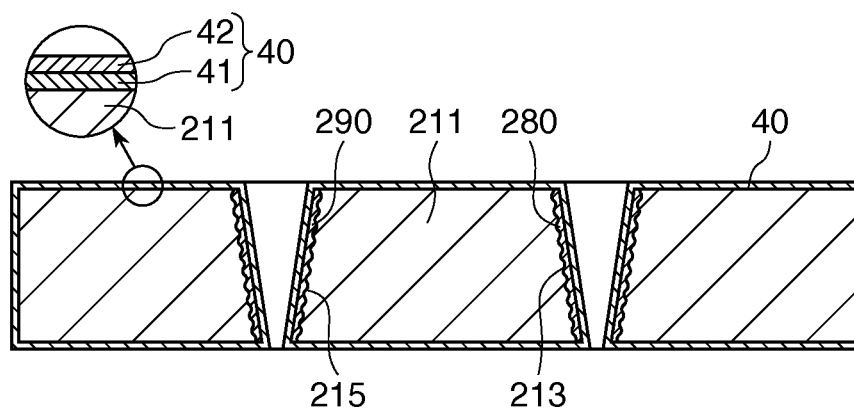


FIG. 6B

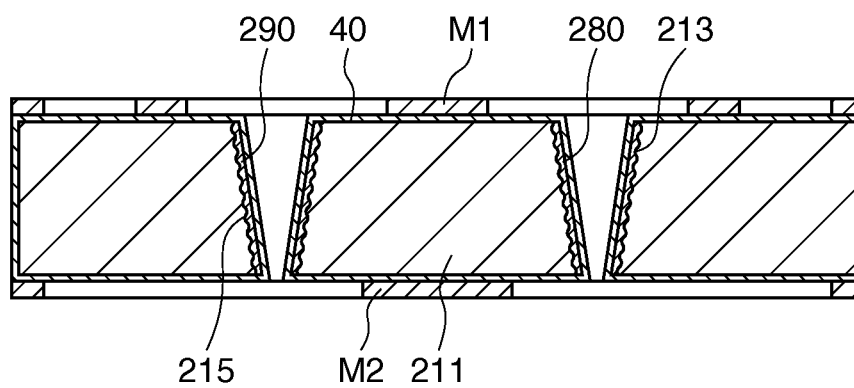


FIG. 6C



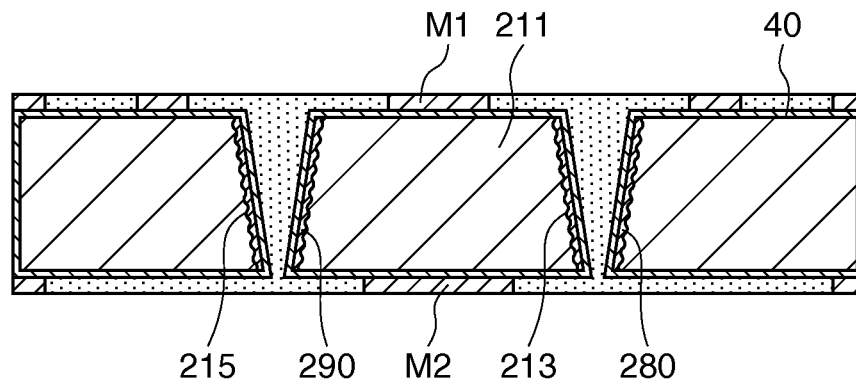


FIG. 7A

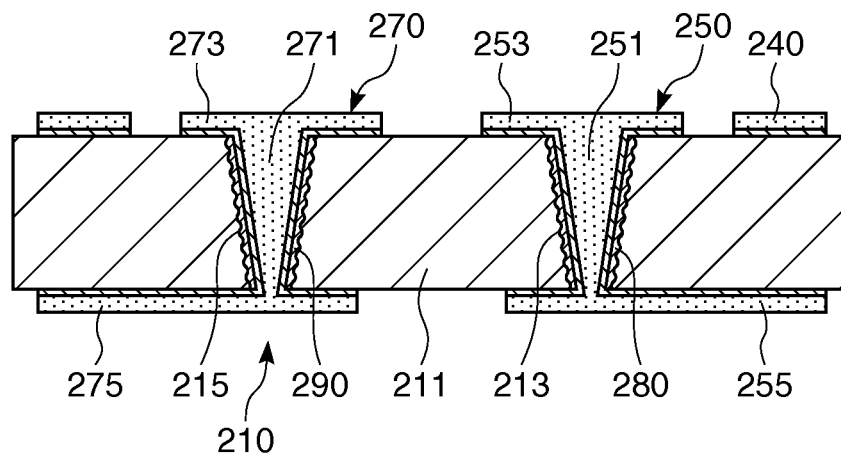


FIG. 7B

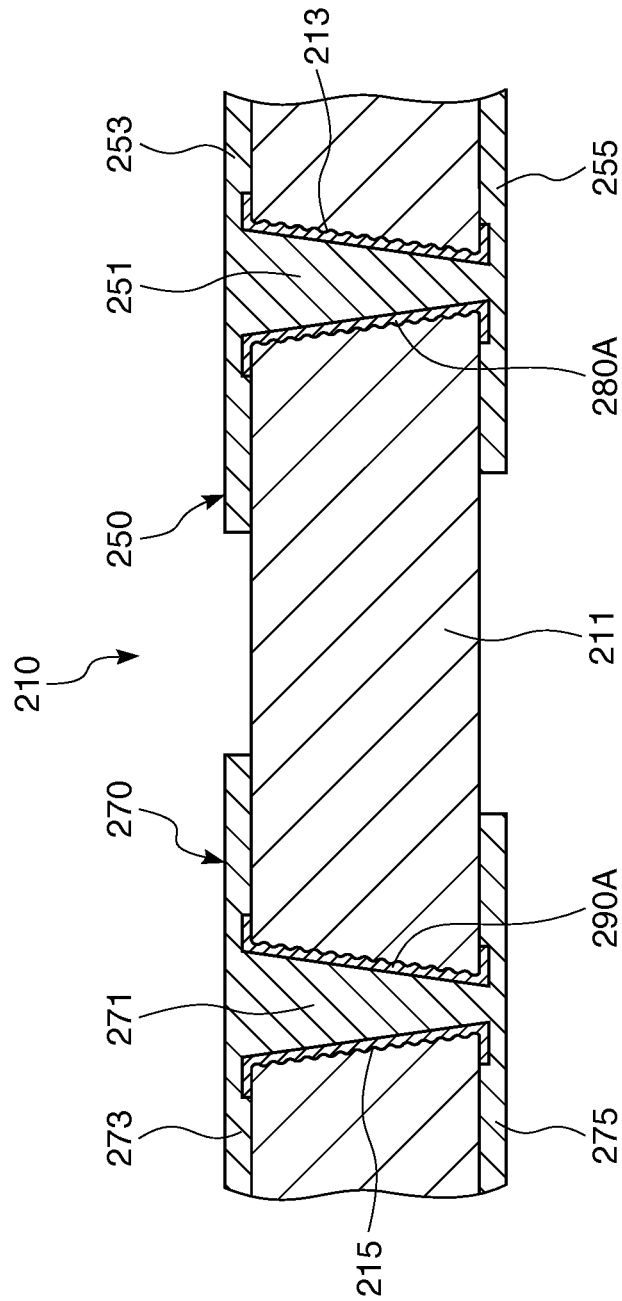


Fig. 8

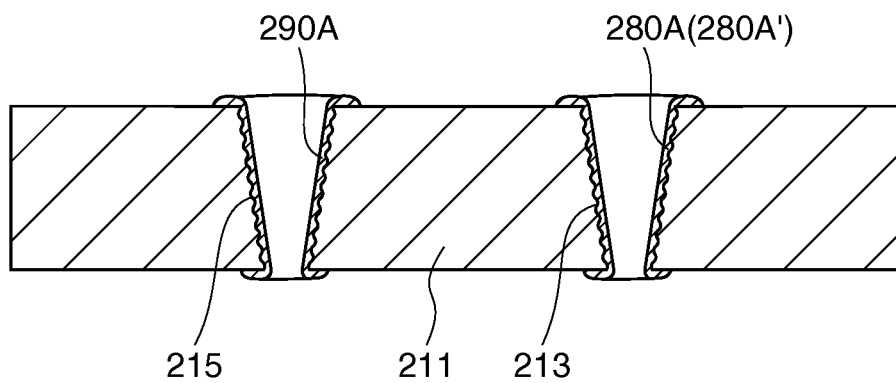


FIG. 9A

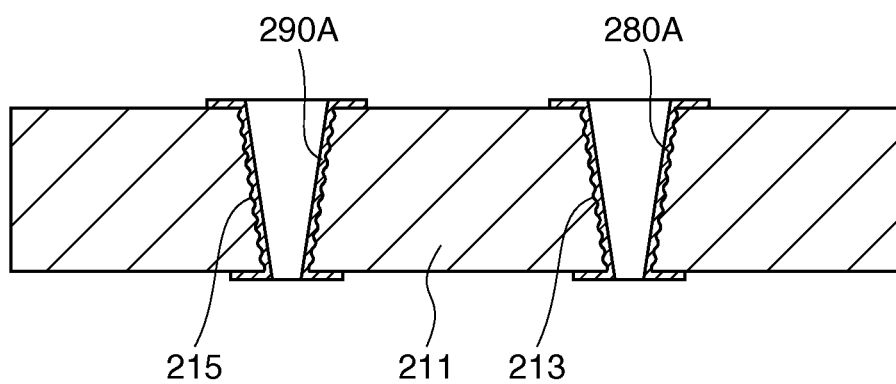


FIG. 9B

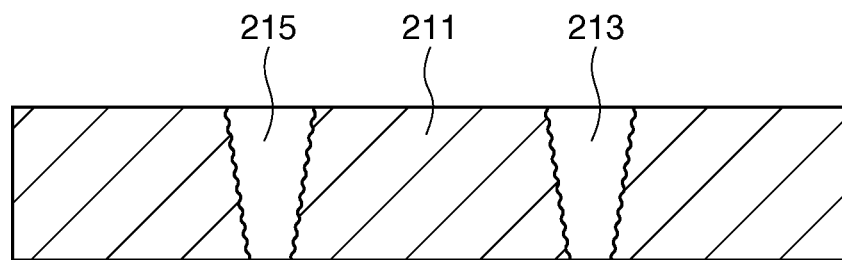


FIG. 10A

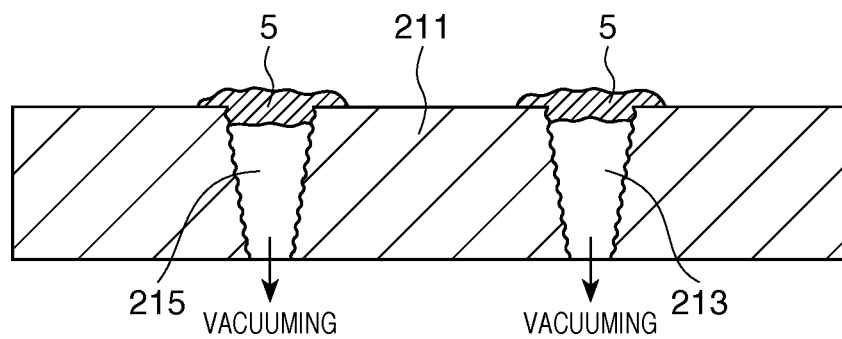


FIG. 10B

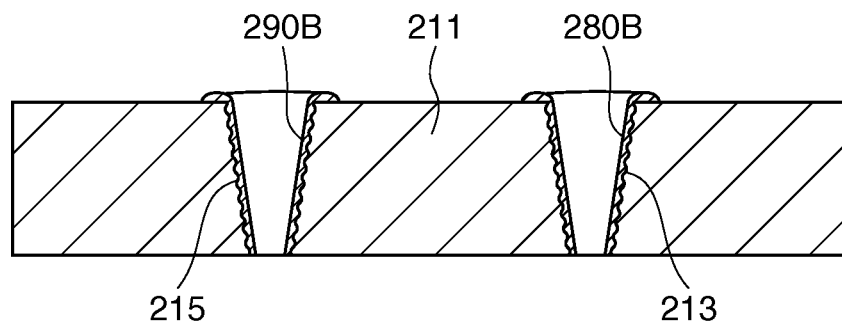


FIG. 10C

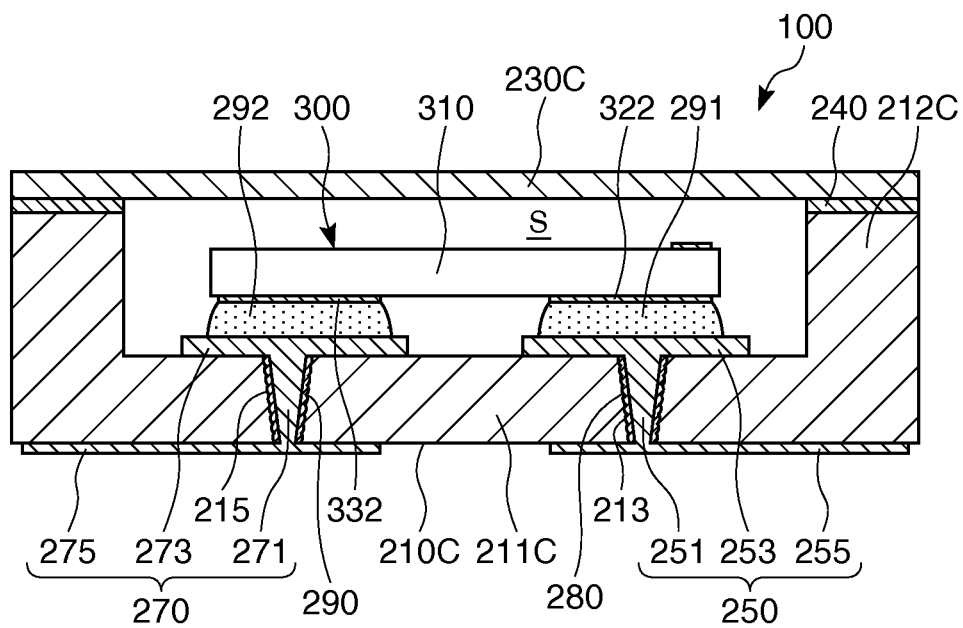


FIG. 11

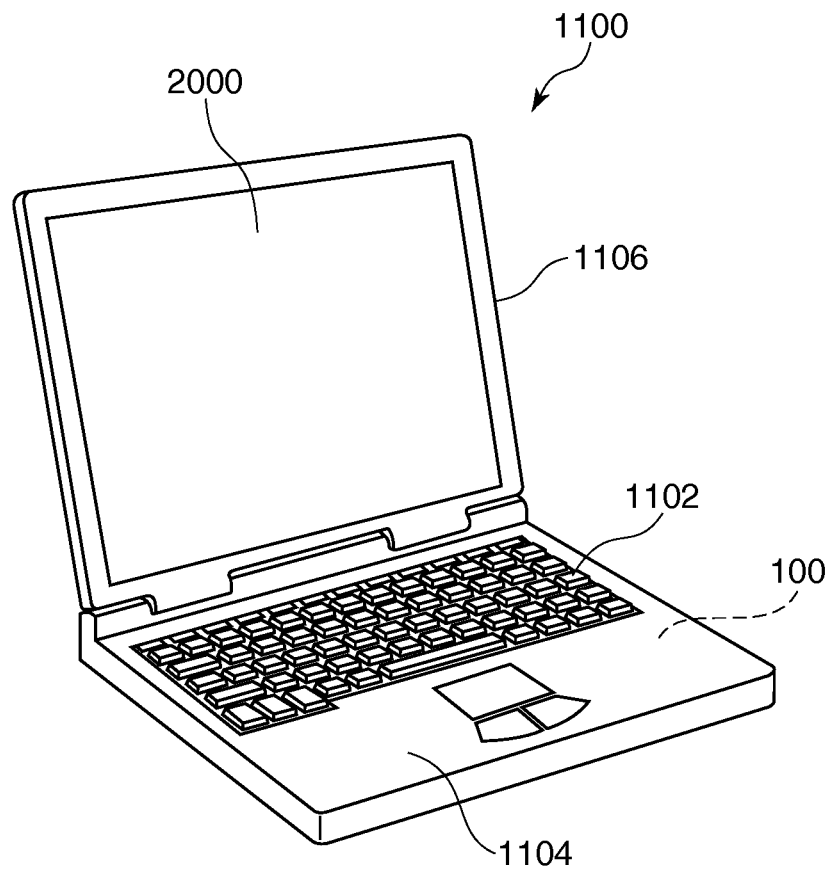


FIG. 12

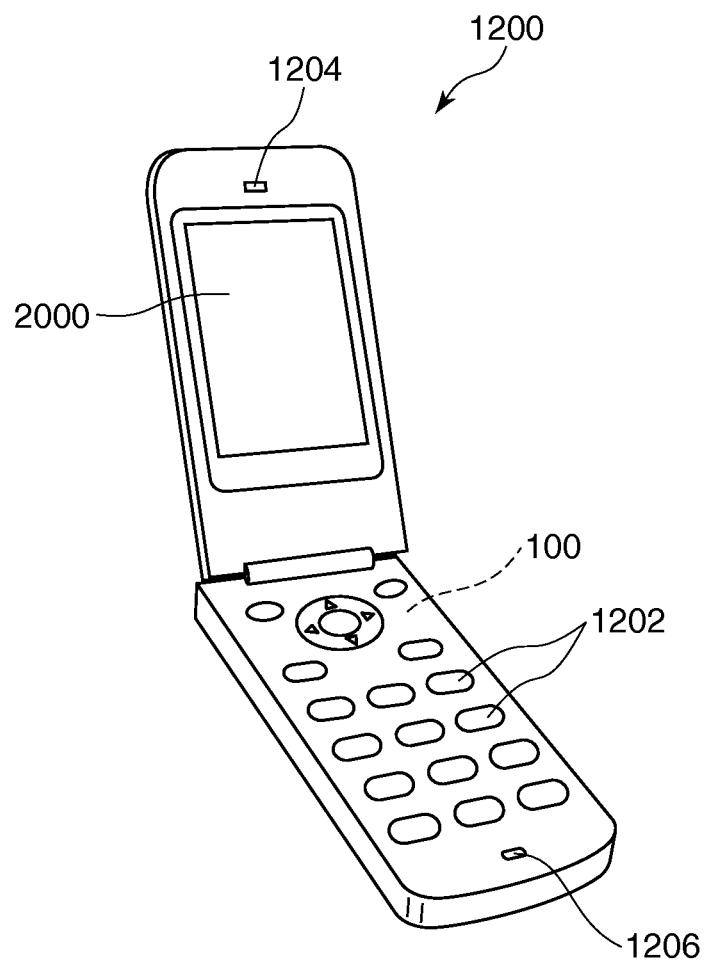


FIG. 13

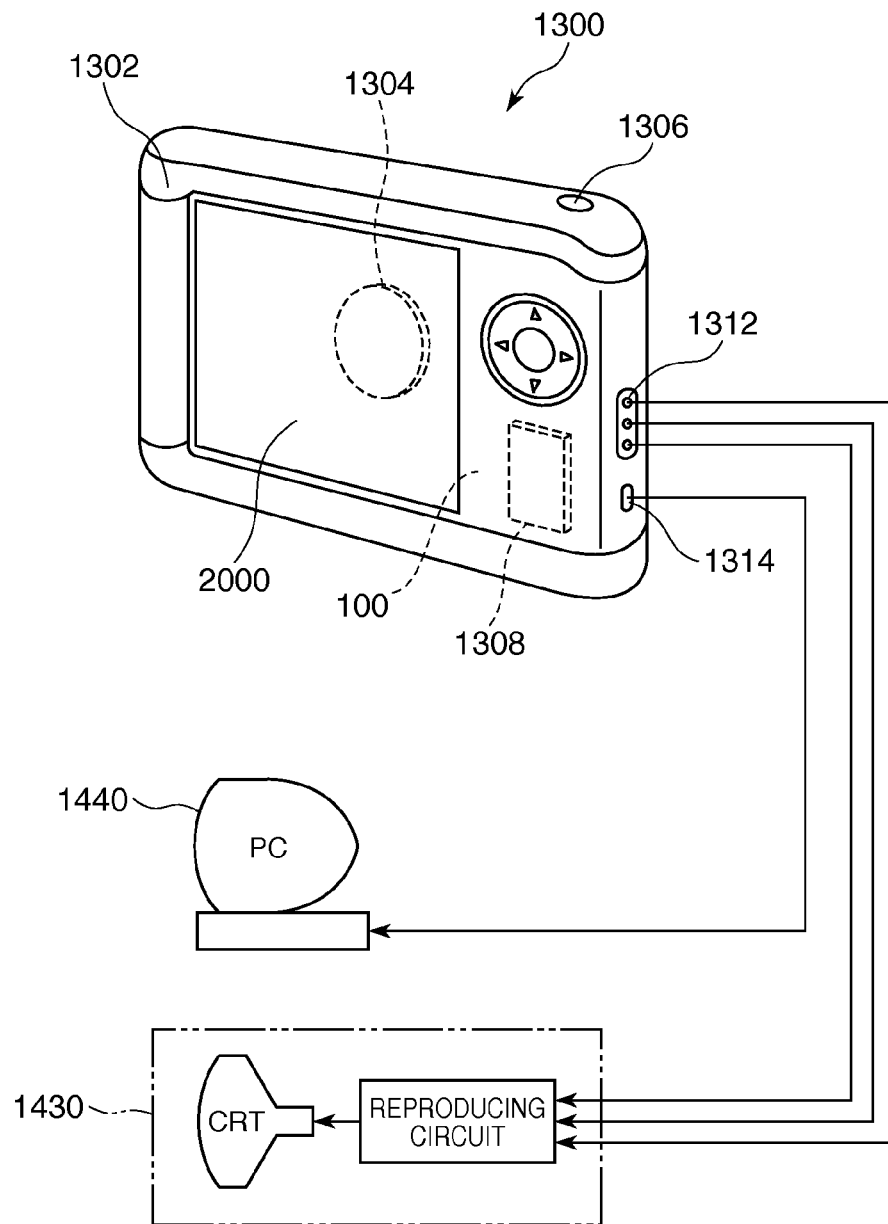


FIG. 14



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# BASE SUBSTRATE, ELECTRONIC DEVICE, AND METHOD OF MANUFACTURING BASE SUBSTRATE

## BACKGROUND

### 1. Technical Field

The present invention relates to a base substrate, an electronic device, and a method of manufacturing the base substrate.

### 2. Related Art

In related art, electronic devices in which electronic components such as piezoelectric elements are housed in packages have been known. A general electronic device air-tightly houses a piezoelectric element in a housing space (internal space) of a package formed by bonding a base substrate and a lid. Further, the base substrate has a ceramics board, connecting electrodes formed on the upper surface of the ceramics board, mounting electrodes formed on the lower surface of the ceramics board, and penetrating electrodes formed through the ceramics board for connecting the connecting electrodes and the mounting electrodes.

Further, as the configuration of the base substrate, a configuration disclosed in Patent Document 1 (JP-A-2007-180924) has been known. A base substrate in Patent Document 1 has a board in which through holes are formed, connecting terminals formed on the upper surface of the board, mounting electrodes formed on the lower surface of the board, and penetrating electrodes formed on the inner surfaces of the through holes for connecting the connecting electrodes and the mounting electrodes. In the base substrate, the penetrating electrodes are formed in films, and the through holes are not filled depending on the penetrating electrodes. Accordingly, in Patent Document 1, the through holes are filled with sealing members and air-tightly sealed.

However, in the base substrate, there is a problem that gaps are easily caused between the through holes and the penetrating electrodes and between the penetrating electrodes and the sealing members, and the outside and the inside of the housing space communicate via the gaps and the air-tightness of the housing space is lost. Further, there is another problem that the penetrating electrodes are formed in thin films, and disconnection is easily caused. Particularly, on the inner surfaces of the through holes, minute concavities and convexities caused at the formation exist and, when the penetrating electrodes are formed by sputtering or evaporation, it is hard for the materials to attach to the concavities behind the convexities and it is impossible to form uniform films. On this account, the problem that disconnection is easily caused becomes more significant.

## SUMMARY

An advantage of some aspects of the invention is to provide a base substrate having advantageous air-tightness and electrical characteristics, an electronic device with high reliability using the base substrate, and a method of manufacturing a base substrate having advantageous air-tightness and electrical characteristics.

The invention can be implemented as the following forms or application examples.

### APPLICATION EXAMPLE 1

A base substrate according to this application example of the invention includes an insulator board having a through hole penetrating between two opposed principal surfaces, a

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penetrating electrode provided within the through hole, and an intermediate layer sandwiched between an inner surface of the through hole and the penetrating electrode and comprising a surface with smaller concavities and convexities than those of the inner surface at the penetrating electrode side.

The concavities and convexities on the inner surface of the through hole are filled with the intermediate layer, and the penetrating electrode may be formed within the through hole more reliably. Therefore, disconnection of the penetrating electrode, production of a gap between the penetrating electrode and the inner surface of the through hole may be prevented, and the base substrate that may exert advantageous air-tightness and electrical characteristics may be provided.

### APPLICATION EXAMPLE 2

In the base substrate according to the application example of the invention, it is preferable that a principal surface-side electrode electrically connected to the penetrating electrode and covering and opening of the through hole is provided at least at a side of one principal surface of the two principal surfaces.

Thereby, the through hole is closed by the principal surface-side electrode, and thus, the air-tightness may be secured more reliably.

### APPLICATION EXAMPLE 3

In the base substrate according to the application example of the invention, it is preferable that the intermediate layer extends to between the principal surface-side electrode and the one principal surface.

Thereby, for example, the intermediate layer may intervene between the principal surface-side electrode and the insulator board, and thus, the adhesion between the principal surface-side electrode and the insulator board may be improved.

### APPLICATION EXAMPLE 4

In the base substrate according to the application example of the invention, it is preferable that the insulator board contains a glass material.

Thereby, the intermediate layer may be formed more easily and the surface of the intermediate layer may be made smoother.

### APPLICATION EXAMPLE 5

An electronic device according to this application example of the invention includes the base substrate according to the application example of the invention, and an electronic component mounted on the base substrate.

Thereby, the electronic device with high reliability may be obtained.

### APPLICATION EXAMPLE 6

A method of manufacturing a base substrate according to this application example of the invention includes preparing an insulator board, forming a through hole penetrating between two opposed principal surfaces of the insulator board and an intermediate layer bonded to an inner surface of the through hole and comprising a surface with smaller concavities and convexities than those of the inner surface while maintaining a penetrating state of the through hole, and forming a penetrating electrode within the through hole by depositing a metal material on the intermediate layer.

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Thereby, the disconnection of the penetrating electrode, the production of a gap between the penetrating electrode and the inner surface of the through hole may be prevented, and the base substrate that may exert advantageous air-tightness and electrical characteristics may be easily manufactured.

## APPLICATION EXAMPLE 7

In the method of manufacturing the base substrate according to the application example of the invention, it is preferable that the insulator board includes a ceramics material, and forming the through hole and the intermediate layer includes melting and hardening a part of the insulator board.

Thereby, the intermediate layer may be easily formed.

## APPLICATION EXAMPLE 8

In the method of manufacturing the base substrate according to the application example of the invention, it is preferable that forming the through hole and the intermediate layer includes forming the through hole and the intermediate layer by irradiating the insulator substrate with laser.

Thereby, the through hole and the intermediate layer may be formed in the same process, and the number of manufacturing steps may be reduced. Further, the intermediate layer may be easily formed.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described with reference to the accompanying drawings, wherein like numbers reference like elements.

FIG. 1 is a plan view of an electronic device according to a first embodiment of the invention.

FIG. 2 is a sectional view along line A-A in FIG. 1.

FIGS. 3A and 3B are plan views of a vibrating element of the electronic device shown in FIG. 1.

FIG. 4 is a partially enlarged sectional view of a base substrate of the electronic device shown in FIG. 1.

FIGS. 5A to 5C are diagrams for explanation of a method of manufacturing the base substrate shown in FIG. 4.

FIGS. 6A to 6C are diagrams for explanation of the method of manufacturing the base substrate shown in FIG. 4.

FIGS. 7A and 7B are diagrams for explanation of the method of manufacturing the base substrate shown in FIG. 4.

FIG. 8 is an enlarged sectional view of a base substrate of a second embodiment of the electronic device of the invention.

FIGS. 9A and 9B are sectional views for explanation of a method of manufacturing the base substrate shown in FIG. 8.

FIGS. 10A to 10C are sectional views for explanation of a method of manufacturing a base substrate of a third embodiment of the electronic device of the invention.

FIG. 11 is a sectional view showing a fourth embodiment of the electronic device of the invention.

FIG. 12 is a perspective view showing a configuration of a mobile (or notebook) personal computer to which an electronic apparatus including the electronic device of the invention is applied.

FIG. 13 is a perspective view showing a configuration of a cellular phone (including PHS) to which the electronic apparatus including the electronic device of the invention is applied.

FIG. 14 is a perspective view showing a configuration of a digital still camera to which the electronic apparatus including the electronic device of the invention is applied.

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## DESCRIPTION OF EXEMPLARY EMBODIMENTS

As below, a base substrate, a method of manufacturing the base substrate, an electronic device, and an electronic apparatus of the invention will be explained in detail with reference to embodiments shown in the accompanying drawings.

## 1. Electronic Device

## First Embodiment

First, the first embodiment of an electronic device to which a base substrate of the invention is applied (an electronic device of the embodiment of the invention) will be explained.

FIG. 1 is a plan view of an electronic device according to the first embodiment of the invention, FIG. 2 is a sectional view along line A-A in FIG. 1, FIGS. 3A and 3B are plan views of a vibrating element of the electronic device shown in FIG. 1, FIG. 4 is a partially enlarged sectional view of a base substrate of the electronic device shown in FIG. 1, and FIGS. 5A to 5C, 6A to 6C, and 7A and 7B are diagrams for explanation of a method of manufacturing the base substrate shown in FIG. 4. Note that, as below, for convenience of explanation, the explanation will be made with the upside in FIG. 1 as "upper" and the downside as "lower" (the same will apply to the other drawings).

As shown in FIG. 1, an electronic device **100** has a package **200**, and a vibrating element **300** as an electronic component housed within the package **200**.

## Vibrating Element

FIG. 3A is a plan view of the vibrating element **300** as seen from above, and FIG. 3B is a perspective view (plan view) of the vibrating element **300** as seen from above.

As shown in FIGS. 3A and 3B, the vibrating element **300** includes a piezoelectric board **310** having a plan view shape of a rectangular plate, and a pair of exciting electrodes **320**, **330** formed on the surface of the piezoelectric board **310**.

The piezoelectric board **310** is a quartz raw board that mainly performs thickness slip vibration. In the embodiment, as the piezoelectric board **310**, a quartz raw board cut out at a cut angle called AT cut is used. Note that the AT cut refers to cutting out such that the board may have a principal surface (principal surface containing the X-axis and the Z'-axis) obtained by rotation of a plane containing the X-axis and the Z-axis as crystal axes of quartz (Y-plane) from the Z-axis around the X-axis to about 35 degrees 15 minutes in the counter-clockwise direction.

The piezoelectric board **310** having the configuration has the longitudinal direction aligned with the X-axis as the crystal axis of quartz.

The exciting electrode **320** has an electrode part **321** formed on the upper surface of the piezoelectric board **310**, a bonding pad **322** formed on the lower surface of the piezoelectric board **310**, and a wire **323** that electrically connects the electrode part **321** and the bonding pad **322**. On the other hand, the exciting electrode **330** has an electrode part **331** formed on the lower surface of the piezoelectric board **310**, a bonding pad **322** formed on the lower surface of the piezoelectric board **310**, and a wire **333** that electrically connects the electrode part **331** and the bonding pad **332**.

The electrode parts **321**, **331** are provided to be opposed via the piezoelectric board **310**, and have nearly the same shape as each other. That is, in the plan view of the piezoelectric board **310**, the electrode parts **321**, **331** are formed to be located to overlap with each other so that their outlines may coincide with each other. Further, the bonding pads **322**, **332**

are formed apart in the end part at the right side of FIG. 3C on the lower surface of the piezoelectric board **310**.

These exciting electrodes **320**, **330** may be formed by depositing a foundation layer of nickel (Ni) or chromium (Cr) on the piezoelectric board **310** by evaporation or sputtering, for example, then, depositing an electrode layer of gold (Au) on the foundation layer by evaporation or sputtering, and then, patterning them in desired shapes using a photolithography and various etching technologies. The foundation layer is formed, and thereby, the adhesiveness between the piezoelectric board **310** and the electrode layer is improved and the vibrating element **300** with high reliability is obtained.

Note that, as the configuration of the exciting electrodes **320**, **330**, not limited to the above described configuration, but, for example, the foundation layer may be omitted or their constituent material may be another material having conductivity (e.g., various metal materials including silver (Ag), copper (Cu), tungsten (W), molybdenum (Mo), or the like).

This vibrating element **300** is fixed to the package **200** via a pair of conducting adhesive agents **291**, **292**.

Package

As shown in FIGS. 1 and 2, the package **200** has a base substrate (a base substrate of the embodiment of the invention) **210** in a plate shape, a lid **230** in a cap shape having a recess part opening to the lower side, and a metalization layer **240** intervening between the base substrate **210** and the lid **230** and bonding them. In the package **200**, the opening of the recess part is covered by the base substrate **210**, and thereby, an air-tight housing space S for housing the above described vibrating element **300** is formed.

The lid **230** has a main body **231** in a cylindrical shape with a bottom, and a flange **233** formed on the lower end of the main body **231** (i.e., around the opening of the main body **231**). Further, on the lower surface of the flange **233**, a brazing filler metal **235** is provided in a film to surround the opening. This lid **230** is bonded to the base substrate **210** by welding of the brazing filler metal **235** and the metalization layer **240**. As the brazing filler metal **235**, not particularly limited, but gold solder, silver solder, or the like may be used. The silver solder is preferably used. Further, as the melting point of the brazing filler metal **235**, not particularly limited, but the temperature from 800° C. to 1000° C. is preferable.

Furthermore, as the constituent material of the lid **230**, not particularly limited, but a member having a linear expansion coefficient approximately equal to that of the constituent material of the base substrate **210** (an insulator board **211**) is preferable. For example, when the insulator board **211** is a ceramics board, which will be described later, the lid may be formed using an alloy of kovar or the like.

FIG. 4 is the enlarged sectional view of the base substrate **210**. As shown in the drawing, the base substrate **210** has the plate-like insulator board **211** with two through holes **213**, **215** formed therein, intermediate layers **280**, **290** formed on the inner surfaces of the respective through holes **213**, **215**, and a pair of electrodes **250**, **270** formed on the insulator board **211**.

The insulator board **211** of the embodiment includes a ceramics board. This ceramics board, for example, the insulator board **211** is obtained by preparing ceramics powder (ceramics material) and glass powder (glass material), shaping the material as mixture of these powder raw materials and binder in a sheet shape to obtain a green sheet, and sintering the green sheet. As a mixture ratio of the ceramics material and the glass material, not particularly limited, but, for example, a ratio by weight of about 1:1 is preferable.

The ceramics materials include, for example,  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ ,  $\text{MgO}$ ,  $\text{MgO} \cdot \text{SiO}_2$ ,  $2\text{MgO} \cdot \text{SiO}_2$ , composite oxides having Per-

ovskite structures of  $\text{TiO}_2$ ,  $\text{BaTiO}_3$ ,  $\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$ ,  $\text{SrTiO}_3$ ,  $\text{CaTiO}_3$ ,  $\text{PbZr}_{1-x}\text{Ti}_x\text{O}_3$ ,  $\text{Pb}_{1-x}\text{La}_x\text{ZrTi}_{1-x}\text{O}_3$ ,  $\text{SrBi}_2\text{TaO}_3$ , other ferroelectric materials, or  $\text{MgTiO}_3$ ,  $\text{Ba}(\text{Mg}_{1/3}\text{Ta}_{2/3})\text{O}_3$ ,  $\text{Ba}(\text{Zn}_{1/3}\text{Ta}_{2/3})\text{O}_3$ ,  $\text{Ba}(\text{Ni}_{1/3}\text{Ta}_{2/3})\text{O}_3$ ,  $\text{Ba}(\text{Co}_{1/3}\text{Ta}_{2/3})\text{O}_3$ ,  $\text{BaNd}_2\text{Ti}_4\text{O}_{12}$ ,  $\text{Ba}_2\text{Ti}_9\text{O}_{20}$ ,  $\text{LaAlO}_3$ ,  $\text{PrAlO}_3$ ,  $\text{SmAlO}_3$ ,  $\text{YAlO}_3$ ,  $\text{GdAlO}_3$ ,  $\text{DyAlO}_3$ ,  $\text{ErAlO}_3$ ,  $\text{Sr}(\text{Zn}_{1/3}\text{Ta}_{2/3})\text{O}_3$ ,  $\text{Sr}(\text{Ni}_{1/3}\text{Ta}_{2/3})\text{O}_3$ ,  $\text{Sr}(\text{Co}_{1/3}\text{Ta}_{2/3})\text{O}_3$ ,  $\text{Sr}(\text{Mg}_{3/3}\text{Ta}_{2/3})\text{O}_3$ ,  $\text{Sr}(\text{Ca}_{1/3}\text{Ta}_{2/3})\text{O}_3$ ,  $\text{Ba}_2\text{Ti}_9\text{O}_{20}$ ,  $\text{Ba}(\text{Co}_{1/3}\text{Nb}_{2/3})\text{O}_3$ , or the like.

Further, the glass materials include crystallized glass, amorphous glass, specifically, glass materials containing  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , RO (R is Mg, Ca, Sr, Ba), and specifically,  $\text{SiO}_2$ —BaO based,  $\text{SiO}_2$ — $\text{Al}_2\text{O}_3$ —BaO based,  $\text{SiO}_2$ — $\text{Al}_2\text{O}_3$ —BaO— $\text{Ba}_2\text{O}_3$  based,  $\text{SiO}_2$ — $\text{Al}_2\text{O}_3$ —BaO—ZnO— $\text{Ba}_2\text{O}_3$  based glass, Bi-based glass, and glass consisting primarily of them.

Here, the formation of the through holes **213**, **215** in the insulator board **211** is performed after the above described sintering processing. Thereby, the through holes **213**, **215** may be formed with advantageous dimensions and position accuracy. There is a method of forming the through holes **213**, **215** in the green sheet before sintering processing by punching or the like, however, in this method, due to contraction and deflection of the sheet at sintering processing, the dimensions of the through holes **213**, **215** and the positional relationship between each other (distance apart from each other or the like) deviate from the designed values, and advantageous dimensions and position accuracy can not be exerted. On the other hand, according to the method of forming the through holes **213**, **215** after sintering processing, the above described problem does not occur and the through holes **213**, **215** may be formed with the advantageous dimensions and position accuracy.

As the method of forming the through holes **213**, **215**, not particularly limited, but a method of laser processing, sand-blasting, etching, punching, or the like may be used, and the laser processing is used in the embodiment. According to the laser processing, as will be described later, the intermediate layers **280**, **290** may be formed at the same time (in the same process) with the through holes **213**, **215**.

Note that, when the through holes **213**, **215** are formed by laser processing, the through holes **213**, **215** are formed in tapered shapes (conical shapes) in which the opening at the upper surface side as the laser irradiation side is larger in diameter than the opening at the lower surface side. The diameters of the through holes **213**, **215** are not particularly limited, but it is preferable that the diameter of the opening at the upper surface side is about from 50  $\mu\text{m}$  to 100  $\mu\text{m}$  and the diameter of the opening at the lower surface side is about from 20  $\mu\text{m}$  to 50  $\mu\text{m}$ . Thereby, the sufficiently small through holes **213**, **215** are obtained, and downsizing of the electronic device **100** may be realized.

As shown in FIG. 4, the electrode **250** includes a penetrating electrode **251** formed within the through hole **213** to fill the through hole **213**, a connecting electrode (principal-side electrode) **253** formed on the upper surface of the insulator board **211** to overlap with the penetrating electrode **251** (cover the penetrating electrode **251**), and a mounting electrode (principal-side electrode) **255** formed on the lower surface of the insulator board **211** to overlap with the penetrating electrode **251**. In the electrode **250** having the configuration, the connecting electrode **253** and the mounting electrode **255** are electrically connected via the penetrating electrode **251**.

Similarly, the electrode **270** includes a penetrating electrode **271** formed within the through hole **215** to fill the through hole **215**, a connecting electrode (principal-side electrode) **273** formed on the upper surface of the insulator board **211** to overlap with the penetrating electrode **271**, and

amounting electrode (principal-side electrode) **275** formed on the lower surface of the insulator board **211** to overlap with the penetrating electrode **271**. In the electrode **270** having the configuration, the connecting electrode **273** and the mounting electrode **275** are electrically connected via the penetrating electrode **271**.

As the constituent material of these electrodes **250**, **270**, not particularly limited, but, for example, a metal material such as gold (Au), gold alloy, platinum (Pt), aluminum (Al), aluminum alloy, silver (Ag), silver alloy, chromium (Cr), chromium alloy, copper (Cu), molybdenum (Mo), niobium (Nb), tungsten (W), iron (Fe), titanium (Ti), cobalt (Co), zinc (Zn), or zirconium (Zr) may be used.

The formation of the electrodes **250**, **270** may be performed, not particularly limited, but using evaporation, sputtering, screen printing, plating processing, or the like, and preferably using the plating processing. Further, as the plating processing, either of electrolytic plating processing or non-electrolytic plating processing may be used, and the electrolytic plating processing is preferably used. Thereby, the respective parts of the electrode **250**, i.e., the penetrating electrode **251**, the connecting electrode **253**, and the mounting electrode **255** may be integrally formed at the same time (the same applies to the electrode **270**), and thus, the electrodes **250**, **270** may be formed more easily. Further, in the method of forming the electrodes **250**, **270** by attaching the scattered material to the insulator board **211** like evaporation and sputtering, the material does not sufficiently enter the through holes **213**, **215**, and the formation of the penetrating electrodes **251**, **271** may be insufficient. However, in the plating processing, the plating material (the above described metal material) may be grown from inside of the through holes **213**, **215**, and the through holes **213**, **215** may be reliably filled with the plating material. Therefore, according to the plating processing, the desired penetrating electrodes **251**, **271**, i.e., the penetrating electrodes **251**, **271** with which production of gaps (gaps that can be paths of the base) in the boundary parts between the intermediate layers **280**, **290** and themselves or inside are suppressed may be reliably formed.

As shown in FIG. 4, the intermediate layer **280** is formed between the inner surface of the through hole **213** and the penetrating electrode **251**, and the intermediate layer **290** is formed between the inner surface of the through hole **215** and the penetrating electrode **271**. As below, for the explanation of the intermediate layers **280**, **290**, the intermediate layer **280** will be representatively explained and the explanation of the intermediate layer **290** will be omitted because they have the same configuration as each other.

The intermediate layer **280** has a function of intervening between the inner surface of the through hole **213** and the penetrating electrode **251** (being sandwiched between the inner surface of the through hole **213** and the penetrating electrode **251**), and improving the adhesion between them. That is, the intermediate layer **280** functions as a primer layer.

Specifically, regardless of the method of forming the through hole **213**, minute concavities and convexities are formed on the inner wall of the through hole **213**. These concavities and convexities may deteriorate the adhesion between the inner surface of the through hole **213** and the penetrating electrode **251**, produce a gap between the inner surface of the through hole **213** and the penetrating electrode **251**, and further, when the penetrating electrode **251** is formed by sputtering or evaporation, cause insufficient formation of the penetrating electrode **251** because the materials are hard to attach to the concavities behind the convexities.

Accordingly, if the intermediate layer **280** is omitted and the penetrating electrodes **251**, **271** are formed in contact with

the inner surfaces of the through holes **213**, **215** as in related art, a gas enters the housing space **S** from the outside via the through hole **213**, a problem that the air-tightness of the housing space **S** of the package **200** can not be held or a problem that disconnection of the penetrating electrode **251** occurs arises.

The intermediate layer **280** is a layer formed for the purpose of solving the above described problems. The intermediate layer **280** is formed to fill the minute concavities and convexities on the inner surface of the through hole **213**. Further, the surface (inner surface) of the intermediate layer **280** is formed by a relatively flat (smooth) surface. In other words, the intermediate layer **280** has the surface having the smaller concavities and convexities than those of the inner surface of the through hole **213** at the penetrating electrode **251** side.

Furthermore, the thickness (average thickness) of the intermediate layer **280** is not particularly limited as long as it may fill the concavities and convexities on the inner surface of the through hole **213**, but preferably is about from 1  $\mu\text{m}$  to 5  $\mu\text{m}$ . Thereby, the concavities and convexities on the inner surface of the through hole **213** may be sufficiently filled and the thickness of the intermediate layer **280** may be suppressed. Accordingly, the space for formation of the penetrating electrode **251** within the through hole **213** may be sufficiently secured while the diameter of the through hole **213** is suppressed.

This intermediate layer **280** is formed using a material containing a glass material. The material is softened and supplied to the inner surface of the through hole **213**, and thereby, the concavities and convexities on the inner surface of the through hole **213** may be filled easily and reliably, and the intermediate layer **280** having the smooth surface may be formed.

The intermediate layer **280** of the embodiment is a layer formed by hardening (solidification) of the melt of the insulator board **211**. As described above, the through hole **213** is formed by laser processing. That is, the insulator board **211** is irradiated with laser, the part irradiated with laser is gasified (evaporated) and removed, and thereby, the through hole **213** is formed. In this regard, concurrently with the gradual formation of the through hole **213** from the laser application side, the part near the inner wall melts by the heat of the laser and the melt wets and spreads on the inner surface of the through hole **213** to fill the concavities and convexities on the inner surface. Therefore, the through hole **213** and the layer of the melt filling the concavities and convexities on the inner surface are formed at the same time, the layer of the melt is hardened, and thereby, the intermediate layer **280** is formed.

As described above, the melt of the insulator board **211** is hardened to form the intermediate layer **280**, and thereby, the intermediate layer **280** and the insulator board **211** may be formed using the same material and the affinity of them may be improved. Accordingly, the intermediate layer **280** and the insulator board **211** are bonded more strongly with the higher adhesion.

Further, as described above, as the constituent material of the insulator board **211**, the glass material is used in addition to the ceramics material. The glass material is contained, and the surface of the intermediate layer **280** may be made to be the smoother surface without concavities or convexities. Furthermore, the viscosity of the melt may be suitable for wetting and spreading on the inner surface of the through hole **213**, and the intermediate layer **280** may be formed more reliably.

This intermediate layer **280** is formed between the inner surface of the through hole **213** and the penetrating electrode **251**, and thereby, the adhesion of the penetrating electrode

**251** to the through hole **213** may be improved and, as will be explained in the manufacturing method to be described, the penetrating electrode **251** may be formed with desired accuracy more reliably. Accordingly, the leak of the gas via the through hole **213** may be prevented, and the air-tightness of the housing space **S** may be reliably secured. Further, the disconnection of the penetrating electrode **251** may be prevented.

Specifically, in the embodiment, the connecting electrode **253** and the mounting electrode **255** are formed to cover the openings of the through hole **213** (penetrating electrode **251**), and thereby, the through hole **213** may be closed by the connecting electrode **253** and the mounting electrode **255** and the air-tightness of the base substrate **210** may be secured more reliably.

As above, the package **200** has been explained. In the housing space **S** of the package **200**, the vibrating element **300** is housed. The vibrating element **300** housed in the housing space **S** is supported by the base substrate **210** via the pair of conducting adhesive agents **291**, **292**. The conducting adhesive agent **291** is provided in contact with the connecting electrode **253** and the bonding pad **322**, and thereby, the connecting electrode **253** and the bonding pad **322** are electrically connected via the conducting adhesive agent **291**. The other conducting adhesive agent **292** is provided in contact with the connecting electrode **273** and the bonding pad **332**, and thereby, the connecting electrode **273** and the bonding pad **332** are electrically connected via the conducting adhesive agent **292**.

Next, a method of manufacturing the base substrate **210** (a method of manufacturing a base substrate of the embodiment of the invention) will be explained.

The method of manufacturing the base substrate **210** has a step of preparing the insulator board **211**, a step of forming the through holes **213**, **215** penetrating between two opposed principal surfaces of the insulator board **211** and the intermediate layers **280**, **290** bonded to the inner surfaces of the through holes **213**, **215** and having surfaces with the smaller concavities and convexities than those of the inner surfaces while maintaining the penetrating states of the through holes **213**, **215**, and a step of forming the penetrating electrodes **251**, **271** within the through holes **213**, **215** by depositing a metal material on the intermediate layers **280**, **290**. As below, these steps will be explained in detail.

First, as shown in FIG. 5A, the insulator board **211** as a ceramics board is prepared. As described above, the insulator board **211** may be manufactured by forming mixture of material powder containing ceramics powder (ceramics material) and glass powder (glass material) and binder in a sheet shape by the doctor blade method or the like to obtain a ceramic green sheet, and sintering the obtained ceramic green sheet, for example. In this regard, it is preferable that the ceramic green sheet is single-layered. Thereby, the manufacturing cost may be reduced. Further, deflection and warpage of the insulator board **211** may be suppressed.

Then, as shown in FIG. 5B, the insulator board **211** is irradiated with laser from the upper surface side toward the part in which the through hole **213** is to be formed and gasifying and removing the irradiated part, and thereby, a hole **213'** to be the through hole **213** is bored toward the lower surface. Concurrently, the part near the inner surface of the hole **213'** melts by the heat of the laser and the melt wets and spreads to cover the inner surface of the hole **213'**. That is, as the hole **213'** is bored, the melt of the insulator board **211** wets and spreads on the inner surface. Then, as shown in FIG. 5C, the hole **213'** reaches the lower surface of the insulator board **211**, and thereby, the through hole **213** is formed and a melt

layer **280'** including the melt is formed on the inner surface. Then, the melt layer **280'** is hardened and the intermediate layer **280** is obtained. The through hole **215** and the intermediate layer **290** are formed in the same manner. Thereby, the intermediate layers **280**, **290** having surfaces with the smaller concavities and convexities than those of the inner surfaces of the through holes **213**, **215** are obtained.

Note that, as shown in FIG. 6A, the melt may also wet and spread to the opening end surfaces of the through holes **213**, **215** (the upper surface and the lower surface of the insulator board **211**), and the intermediate layers **280**, **290** may be formed in the parts. In this case, the intermediate layers **280**, **290** formed on the opening end surfaces of the through hole **213** are removed by polishing.

Then, as shown in FIG. 6B, a metal film **40** having conductivity is formed on the surface of the insulator board **211** by evaporation or sputtering. The metal film **40** functions as a seed layer for the subsequent electrolytic plating processing. Note that the concavities and convexities on the inner surfaces of the through holes **213**, **215** are covered by the intermediate layers **280**, **290**, and the surfaces (smooth surfaces) of the intermediate layers **280**, **290** are exposed inside of the through holes **213**, **215**. Accordingly, the uniform metal film **40** may be formed without irregularities inside of the through holes **213**, **215**.

The metal film **40** may be single-layered or multi-layered. The metal film **40** of the embodiment includes a first metal film **41** of titanium-tungsten alloy or chromium, and a second metal film **42** of copper formed on the first metal film **41**. Copper plating is performed as the electrolytic plating processing as will be described later, copper is used as the constituent material of the second metal film **42**, and the adhesion of the plated layer formed on the second metal film **42** may be improved. Note that the constituent materials of the first metal film **41** and the second metal film **42** are not limited to those described above.

Then, as shown in FIG. 6C, a first mask **M1** is formed on the upper surface of the insulator board **211**, and a second mask **M2** is formed on the lower surface of the insulator board **211**. The first mask **M1** has openings corresponding to the plan view shapes of the connecting electrodes **253**, **275** and the metallization layer, and the second mask **M2** has openings corresponding to the plan view shapes of the mounting electrodes **255**, **275**. Then, copper plating is performed on the metal film **40** by electrolytic plating processing, and thereby, as shown in FIG. 7A, a copper film **45** is grown in the parts exposed from the openings of the first and second masks. In this regard, the metal film **40** as the seed layer is uniformly formed as described above, and the copper film **45** is uniformly grown without irregularities on the metal film **40**. Then, the first and second masks **M1** and **M2** are removed, and then, the metal film **40** exposed from the copper film **45** is removed by etching or otherwise. Thereby, the electrodes **250**, **270** and the metalization layer **240** may be formed. In this manner, as shown in FIG. 7B, the base substrate **210** is obtained.

As described above, the through holes **213**, **215** are formed on the insulator board **211** by laser processing, thereby, the through holes **213**, **215** and the intermediate layers **280**, **290** may be formed at the same time (in the same process), and thus, the manufacture of the base substrate **210** is easier. Further, the electrode **250** is formed by plating processing, thereby, the respective parts of the electrode **250** (the penetrating electrode **251**, the connecting electrode **253**, and the mounting electrode **255**) may be integrally formed, and thus, the formation of the electrode **250** is easier (the same applies to the electrode **270**).

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Note that, in the above described manufacturing method, the electrodes **250**, **270** are formed by forming the first and second masks **M1** and **M2**, then, forming the copper film **45**, and then, removing the unnecessary parts of the metal film **40**, however, not limited to that. For example, the electrodes **250**, **270** may be formed by forming the copper film **45** uniformly on the metal film **40**, forming the first and second masks **M1** and **M2** on the copper film **45**, and etching the copper film **45** and the metal film **40** via the first and second masks **M1** and **M2**.

### Second Embodiment

Next, the second embodiment of the electronic device of the invention will be explained.

FIG. **8** is an enlarged sectional view of a base substrate of the second embodiment of the electronic device of the invention, and FIGS. **9A** and **9B** are sectional views for explanation of a method of manufacturing the base substrate shown in FIG. **8**.

As below, regarding the second embodiment, the difference from the above described embodiment will be centered for explanation and the explanation of the same items will be omitted.

The electronic device according to the second embodiment of the invention is the same as the electronic device of the first embodiment except that the formation ranges of the intermediate layers are different. The same configurations as those of the above described first embodiment have the same signs.

As shown in FIG. **8**, an intermediate layer **280A** is formed to extend from the inner surface of the through hole **213** to the opening end surfaces of the through hole **213**, and extend to between the upper surface of the insulator board **211** and the connecting electrode **253** and between the lower surface of the insulator board **211** and the mounting electrode **255**. That is, the intermediate layer **280A** is formed on the inner surface of the through hole **213**, around the opening of the through hole **213** on the upper surface of the insulator board **211**, and around the opening of the through hole **213** on the lower surface of the insulator board **211**.

Similarly, an intermediate layer **290A** is formed to extend from the inner surface of the through hole **215** to the opening end surfaces of the through hole **215**.

The intermediate layers **280A**, **290A** have the above described configurations, thereby, the intermediate layers **280A**, **290A** may intervene between the upper surface and the lower surface of the insulator board **211** and the electrodes **250**, **270** (the connecting electrodes **253**, **273** and the mounting electrodes **255**, **275**), and thus, the adhesion between the insulator board **211** and the electrodes **250**, **270** may be improved and production of gaps between them may be prevented more effectively. Further, the boundary parts between the inner surfaces of the through holes **213**, **215** and the upper and lower surfaces of the insulator board **211** are cornered and gaps may be easily formed therein, however, the parts may be covered by the intermediate layers **280A**, **290A** and thereby, the above described formation of gaps may be suppressed. Therefore, the base substrate **210** may exert more advantageous air-tightness.

Next, a method of manufacturing a base substrate **210A** will be explained. When the through hole **213** is formed by laser processing as in the first embodiment, the melt of the insulator board **211** wets and spreads on the inner surface and the opening end surfaces of the through hole **213** and a melt layer **280A'** is formed. Then, the melt layer **280A'** is hardened, and thereby, as shown in FIG. **9A**, the intermediate layer **280A** extending from the inner surface to the opening end

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surfaces of the through hole **213** is obtained. The intermediate layer **290A** is formed in the same manner.

As shown in FIG. **9A**, the thicknesses of the intermediate layers **280A**, **290A** formed on the opening end surfaces may be uneven, and, in this case, as shown in FIG. **9B**, the thicknesses of the intermediate layers **280A**, **290A** are made even by polishing or otherwise. Then, the electrodes **250**, **270** are formed by forming the metal layer as the seed layer, forming the first and second masks on the metal layer, and performing the electrolytic plating processing in the same manner as that of the above described first embodiment. Thereby, the base substrate **210A** is obtained.

According to the second embodiment, the same advantages as those of the above described first embodiment may be exerted.

Note that, in the above described second embodiment, the intermediate layers **280A**, **290A** are formed on both of the opening end surfaces of the through holes **213**, **215**, however, for example, the intermediate layers **280A**, **290A** may be formed on only one of the upper opening end surface and the lower opening end surface.

### Third Embodiment

Next, the third embodiment of the electronic device of the invention will be explained.

FIGS. **10A** to **10C** are sectional views for explanation of a method of manufacturing a base substrate of the third embodiment of the electronic device of the invention.

As below, regarding the third embodiment, the difference from the above described embodiments will be centered for explanation and the explanation of the same items will be omitted.

The electronic device according to the third embodiment of the invention is the same as the electronic device of the first embodiment except that the method of forming the intermediate layers is different. The same configurations as those of the above described first embodiment have the same signs.

For example, in the above described first embodiment, when the insulator board **211** does not contain the glass material, if the through holes **213**, **215** are formed by laser processing, the intermediate layers **280**, **290** containing the glass material are not formed at the same time. In this case, intermediate layers **280B**, **290B** may be formed in the manner of the embodiment.

First, as shown in FIG. **10A**, the through holes **213**, **215** are formed on the insulator board **211** by laser processing.

Then, as shown in FIG. **10B**, low-melting-point glass in a liquid state (a glass material in paste form) **5** is applied to the upper surface of the insulator board **211** to cover the upper openings of the through holes **213**, **215** while vacuuming is performed from the lower openings of the through holes **213**, **215**.

Then, as shown in FIG. **10C**, the low-melting-point glass **5** wets and spreads on the inner surfaces toward the lower openings of the through holes **213**, **215** and is hardened, and thereby, the intermediate layers **280B**, **290B** may be formed on the inner surfaces of the through holes **213**, **215**. Then, the electrodes **250**, **270** are formed in the same manner as that of the above described first embodiment, and thereby, the base substrate **210** is obtained.

Note that the method of applying the low-melting-point glass **5** is not particularly limited, but, for example, screen printing or the like may be used. Further, as the low-melting-point glass **5**, for example,  $P_2O_5$ — $CuO$ — $ZnO$ -based low-melting-point glass,  $P_2O_5$ — $SnO$ -based low-melting-point glass,  $B_2O_3$ — $ZnO$ — $Bi_2O_3$ — $Al_2O_3$ -based low-melting-

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point glass, or the like may be used. Or, in place of the low-melting-point glass **5**, paste glass of mixture of glass powder and binder may be used.

According to the third embodiment, the same advantages as those of the above described first embodiment may be exerted.

#### Fourth Embodiment

Next, the fourth embodiment of the electronic device of the invention will be explained.

FIG. **11** is a sectional view showing the fourth embodiment of the electronic device of the invention.

As below, regarding the fourth embodiment, the difference from the above described embodiments will be centered for explanation and the explanation of the same items will be omitted.

The electronic device according to the fourth embodiment of the invention is the same as the electronic device of the first embodiment except that the configuration of the package is different. The same configurations as those of the above described first embodiment have the same signs.

As shown in FIG. **11**, a base substrate **210C** has a cavity shape with a recess part opening to the upper surface. Specifically, the base substrate **210C** has an insulator board **211C** in a plate shape and a wall part **212C** in a frame shape stood from the edge part of the upper surface of the insulator board **211C**. On the other hand, a lid **230C** has a plate shape and the lid **230C** is bonded to the upper surface (opening end surface) of the base substrate **210C** to cover the recess part opening of the base substrate **210C**.

According to the fourth embodiment, the same advantages as those of the above described first embodiment may be exerted.

## 2. Electronic Apparatus

Next, an electronic apparatus to which the electronic device of the embodiment of the invention is applied will be explained in detail with reference to FIGS. **12** to **14**.

FIG. **12** is a perspective view showing a configuration of a mobile (or notebook) personal computer to which the electronic apparatus having the electronic device of the embodiment of the invention is applied. In the drawing, a personal computer **1100** includes a main body unit **1104** having a keyboard **1102** and a display unit **1106** having a display part **2000**, and the display unit **1106** is rotatably supported via a hinge structure part with respect to the main body unit **1104**. The personal computer **1100** contains the electronic device **100** that functions as a filter, a resonator, a reference clock, or the like.

FIG. **13** is a perspective view showing a configuration of a cellular phone (including a PHS) to which the electronic apparatus having the electronic device of the embodiment of the invention is applied. In the drawing, a cellular phone **1200** includes a plurality of operation buttons **1202**, an ear piece **1204**, and a mouthpiece **1206**, and a display part **2000** is provided between the operation buttons **1202** and the ear piece **1204**. The cellular phone **1200** contains the electronic device **100** that functions as a filter, a resonator, or the like.

FIG. **14** is a perspective view showing a configuration of a digital still camera to which the electronic apparatus having the electronic device of the embodiment of the invention is applied. Note that, in the drawing, connection to an external device is simply shown. Here, in a typical camera, a silver halide photographic film is exposed to light by an optical image of a subject and, on the other hand, a digital still camera

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**1300** photoelectrically converts an optical image of a subject using an image sensing device such as a CCD (Charge Coupled Device) and generates imaging signals (image signals).

On a back surface of a case (body) **1302** in the digital still camera **1300**, a display part is provided and adapted to display based on the imaging signals by the CCD, and the display part functions as a finder that displays the subject as an electronic image. Further, on the front side (the rear side in the drawing) of the case **1302**, a light receiving unit **1304** including an optical lens (imaging system), the CCD, etc. is provided.

When a photographer checks the subject image displayed on the display part and presses down a shutter button **1306**, the imaging signals of the CCD at the time are transferred and stored into a memory **1308**. Further, in the digital still camera **1300**, a video signal output terminal **1312** and an input/output terminal for data communication **1314** are provided on the side surface of the case **1302**. Furthermore, as shown in the drawing, a television monitor **1430** is connected to the video signal output terminal **1312** and a personal computer **1440** is connected to the input/output terminal for data communication **1314**, respectively, according to need. In addition, by predetermined operation, the imaging signals stored in the memory **1308** are output to the television monitor **1430** and the personal computer **1440**. The digital still camera **1300** contains the electronic device **100** that functions as a filter, a resonator, or the like.

Note that the electronic apparatus including the electronic device of the embodiment of the invention may be applied not only to the personal computer (mobile personal computer) in FIG. **12**, the cellular phone in FIG. **13**, and the digital still camera in FIG. **14** but also to an inkjet ejection device (for example, an inkjet printer), a laptop personal computer, a television, a video camera, a video tape recorder, a car navigation system, a pager, a personal digital assistance (with or without communication function), an electronic dictionary, a calculator, an electronic game machine, a word processor, a work station, a videophone, a security television monitor, electronic binoculars, a POS terminal, a medical device (for example, an electronic thermometer, a sphygmomanometer, a blood glucose meter, an electrocardiographic measurement system, an ultrasonic diagnostic system, or an electronic endoscope), a fish finder, various measurement instruments, meters and gauges (for example, meters for vehicles, airplanes, and ships), a flight simulator, etc.

As above, the base substrate, the electronic device, and the method of manufacturing the base substrate of the invention have been explained according to the respective illustrated embodiments, however, the invention is not limited to those. The configurations of the respective parts may be replaced by arbitrary configurations having the same functions. Further, other arbitrary configurations may be added. Furthermore, the respective embodiments may be appropriately combined.

Further, in the above described embodiments, the configurations including vibrating elements as electronic components have been explained, however, the electronic components may include, but not be limited to, a gyro sensor or an IC.

The entire disclosure of Japanese Patent Application No. 2012-104087, filed Apr. 27, 2012 is expressly incorporated by reference herein.

What is claimed is:

1. A base substrate comprising:
  - an insulator board comprising a through hole penetrating between two opposed principal surfaces;
  - a penetrating electrode provided within the through hole; and

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an intermediate layer sandwiched between an inner surface of the through hole and the penetrating electrode and comprising a surface with smaller concavities than the inner surface, wherein

the insulating board and the intermediate layer are made of the same material, 5

the insulating board and the intermediate layer are in different states of matter,

a thickness of the intermediate layer is in a range of 1  $\mu\text{m}$  to 5  $\mu\text{m}$ , and 10

the intermediate layer is automatically formed when the through hole is formed by a laser beam.

2. The base substrate according to claim 1, further comprising a principal surface-side electrode electrically connected to the penetrating electrode and covering the through hole at least at a side of one principal surface of the two principal surfaces. 15

3. The base substrate according to claim 2, wherein the intermediate layer extends to between the principal surface-side electrode and the one principal surface. 20

4. An electronic device comprising:

the base substrate according to claim 2, and an electronic component mounted on the base substrate.

5. The base substrate according to claim 1, wherein the insulator board contains a glass material. 25

6. An electronic device comprising:

the base substrate according to claim 1; and

an electronic component mounted on the base substrate.

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7. A method of manufacturing a base substrate comprising: preparing an insulator board;

forming a through hole penetrating between two opposed principal surfaces of the insulator board and an intermediate layer bonded to an inner surface of the through hole at the same time, and the intermediate layer comprising a surface with smaller concavities than the inner surface while maintaining a penetrating state of the through hole; and

forming a penetrating electrode within the through hole by depositing a metal material on the intermediate layer, wherein

the intermediate layer is automatically formed when the through hole is formed by a laser beam, and

a thickness of the intermediate layer is in a range of 1  $\mu\text{m}$  to 5  $\mu\text{m}$ . 15

8. The method of manufacturing the base substrate according to claim 7, wherein the insulator board includes a ceramics material, and

forming the through hole and the intermediate layer includes melting and hardening a part of the insulator board. 20

9. The method of manufacturing the base substrate according to claim 7, wherein, forming the through hole and the intermediate layer includes forming the through hole and the intermediate layer by irradiating the insulator substrate with the laser beam. 25

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